It is IPSC Technical Services' assessment that replacing the Primary Air Heater seals and baskets will not allow the Primary Air Fans on IGS Units 1 and 2 to operate at low speed. Our alternative recommendation is to retrofit the Primary Air Fans with variable frequency drives. The economic justification for this project is as follows:

| | |
|---|---|
| RATE OF RETURN: | 32.7 percent |
| PAYBACK PERIOD: | 3.4 years |
| BENEFIT/COST RATIO: | 4.34 |
| ECONOMIC LIFE: | 20 years |
| PV SAVINGS: | $44,634,531 |
| SALVAGE VALUE: | $150,000 |

Project would include installation of 6.9kV breakers, isolation transformers, dual winding motors, variable frequency drives, DC link reactors, and all wiring and controls. The design would provide for full load operation should one link or motor winding fail. The total project cost is estimated at $11.2 million over 2 years.

IPSC Technical Services has reviewed the "Greenhouse Gas Reduction Feasibility Study" provided to Intermountain Power Agency by Black & Veatch, in March 2008. B&V's recommendation to replace Primary Air Heater (PAH) baskets and seals in order to achieve low speed on the Primary Air (PA) Fans is based on an estimated cold to hot side leakage in the PAH's of 40%.

What the B&V study does not address is the requirement for PA fan discharge pressure to achieve adequate flow through the pulverizers.

Based on operational experience over varying coal qualities and seasonal conditions, IPSC has found that a minimum PA Fan discharge pressure of 52 INWC is required for reliable unit operation. Unit instability is the result of running at a lower PA duct pressure. Without adequate duct pressure, pulverizers begin to load up and this results in sporadic flame destabilizing surges of coal delivered to the burners. Maintaining a higher PA duct pressure eliminates this problem.

Other factors to consider with regard to PA duct pressure:

1. Coal Constituents — Future coal supplies are expected to be higher in ash and have lower heat rate, which will dictate an increase of duct pressure to maintain coal throughput in the pulverizers.

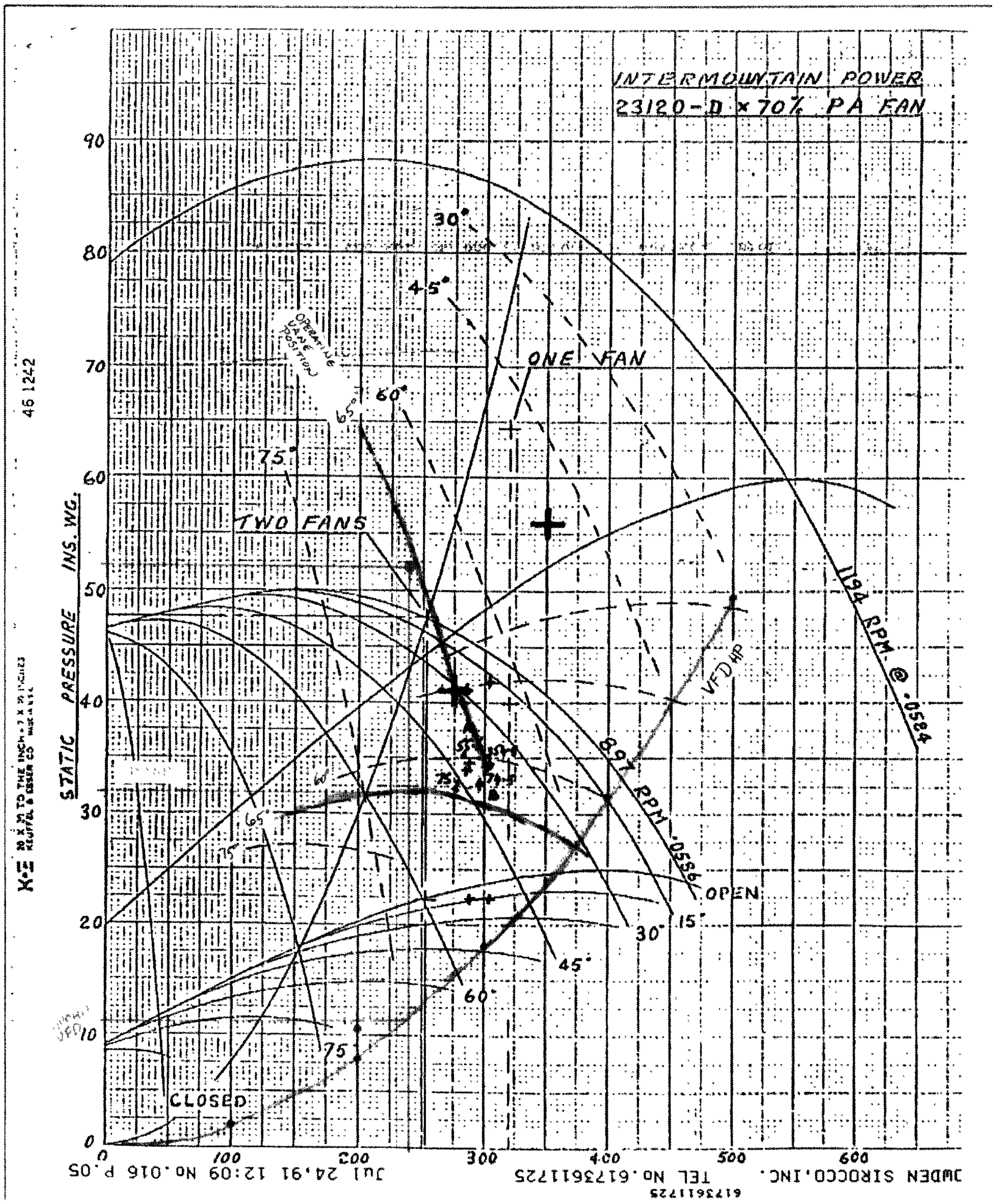
2. Coal Pulverizers — On occasion, 6 mill operation is required. This necessitates a higher duct pressure to maintain coal throughput and maintain load.

The PA Fan curve attached shows a maximum discharge pressure of 50 INWC on low speed. This is a dangerous point to operate at, as any upset condition would result in a unit runback or unstable operation.

The approximate current operating point is identified on the attached fan curve. As can be seen, it is just above the low speed curve, which makes high speed operation very inefficient. This point is achieved by throttling the inlet guide vanes, to the extent that the temperature difference from the inlet of the fan to the outlet is 50° F. The heating of this volume of air indicates a tremendous waste of motor horsepower. The auxiliary power cost associated with operating at this inefficient point equates to $2.4 million per year.

In addition, the 2 speed Pole Amplitude Modulated (PAM) motors currently used on the PA Fans are very inefficient (68%). New induction motors would provide 97% efficiency at full speed. Additionally, the VFD's could be tuned to provide a motor power factor of near 1.0 at the actual operating point. The cost savings recovered by operating at a more efficient motor total $1.5 million per year. This results in a total annual savings of $3.9 million.

If carbon taxes are imposed at the $20/ton of $CO_2$ emitted the payback would drop to 2.1 years. At $40/ton the payback drops to 1.5 years.


INTERMOUNTAIN POWER
23120-D × 70% PA FAN
STATIC PRESSURE INS. WG.
ONE FAN
TWO FANS
OPERATING VANE POSITION
1194 RPM @ .0584
897 RPM .0556
VFD HP
OPEN
CLOSED
30°
45°
60°
75°
65°
15°
0
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
46 1242

IP12_004617

## Calculate Efficiency Saving for Change from Pole Amplitude Modulation Motor to Induction Motor

| | |
|---|---|
| $C_p := 50 \cdot \frac{dollars}{M \cdot W \cdot hr}$ | Cost of Replacement Power |
| $A := 0.91$ | Availibility Factor |
| $H_y := A \cdot 8760 \cdot \frac{hr}{yr}$ | Hours per year - (factoring in availability) |
| $n := 4$ | Number of PA Fans |
| $\eta_1 := 68\%$ | Efficiency of PAM Motor at operating speed (as measured by PDMA) |
| $\eta_2 := 80\%$ | Conservative Estimate of Efficiency of 6600V Induction Motor at 90% speed |
| $\eta_{vfd} := 98\%$ | Estimated VFD Efficiency |
| $P_1 := 3533 \cdot kW$ | Input Power Required to run PA Fan at Operating Point (as measured by PDMA) |
| $P_2 := \frac{820}{\eta_2 \cdot \eta_{vfd}} \cdot kW$ | Calculated Input Power Required to run PA Fan at Operating Point with VFD |
| $L_1 := (1 - \eta_1) \cdot P_1$ | Power Loss due to efficiency factor of PAM Motor |
| $L_2 := (1 - \eta_2) \cdot P_2$ | Power Loss due to efficiency factor of Induction Motor with VFD |
| $L := L_1 - L_2$ | Power Savings for changing to Induction Motor with VFD |
| $S_m := n \cdot L \cdot H_y \cdot C_p$ | Savings for changing from PAM to Induction Motors |

$$S_m = 1468969 \cdot \frac{dollars}{yr}$$

## Calculate Saving for Use of VFD versus Inlet Guide Vanes for PA Fan turndown

$P_1 := 3150 \cdot hp$

Brake Horsepower required to operate PA Fans on high speed and desired operating point.

$P_2 := 1100 \cdot hp$

Calculated Brake Horspower Required to operate PA Fans at desired operating point with a VFD.

$$S_f := \left(P_1 - P_2\right) \cdot n \cdot H_y \cdot C_p$$

$$S_f = 2437213 \cdot \frac{dollars}{yr}$$

Savings for using VFD vs. IGV's

$$S_T := S_m + S_f$$

$$S_T = 3906181 \cdot \frac{dollars}{yr}$$

Total Saving for using VFD and Induction motor vs. IGV and PAM motor.

IP12_004619

## Calculation of power as a function of flow from Fan Law

$P_{igv} := 6000$ Max HP of PA Fan in high speed with IGV's wide open

$Q_{igv} := 550000$ Flow in CFM of PA Fan at max HP

$$Q_{vfd} := \begin{pmatrix} 100000 \\ 200000 \\ 300000 \\ 400000 \\ 500000 \end{pmatrix}$$

Range of flows in CFM to be evaluated

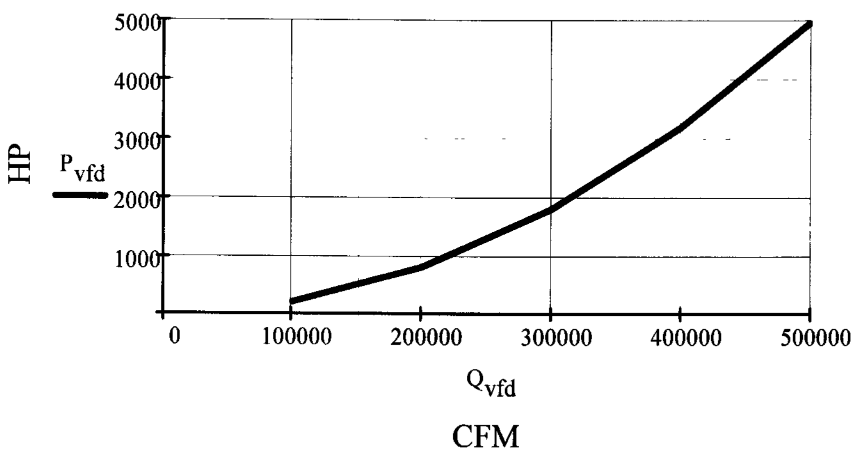
$$P_{vfd} := P_{igv} \cdot \left( \frac{Q_{vfd}}{Q_{igv}} \right)^2$$

Fan Law

$$P_{vfd} = \begin{pmatrix} 198 \\ 793 \\ 1785 \\ 3174 \\ 4959 \end{pmatrix}$$

Range of HP for VFD

VFD Power out as a Function of Air Flow




IP12_004620

# Economic Calculation

**Project Title:** PA Fan VFD's

**Work Order:** Enter WO number here

**Date:** August 6, 2008

## Assumptions:

| | |
|---|---|
| $n := 20$ | Expected Equipment/Project Life |
| $P_o := 13500000 \cdot dollars$ | Initial Project Cost |
| $L_o := 150000 \cdot dollars$ | Salvage Value of Old Equipment |
| $S_o := 0 \cdot dollars$ | Initial One Time Savings |
| $Q_c := 0 \cdot ton$ | Uniform Annual Coal Savings |
| $Q_{fo} := 0 \cdot gal$ | Uniform Annual Fuel Oil Savings |
| $Q_p := 0 \cdot MW \cdot hr$ | Uniform Annual Power Savings |
| $S_m := 3900000 \cdot dollars$ | Uniform Misc Annual Savings |
| $C_a := 20000 \cdot dollars$ | Uniform Annual O&M Costs of New Equipment |
| $L_n := 0 \cdot dollars$ | Future Salvage Value of Equipment at the End of the Project Life |

**Notes:** Salvage of PAM motors $150,000. $20,000 annual cost to include energy for cooling system, maintenance, etc...

## Calculations:

**Net Project Cost**

$P_c := P_o - L_o - S_o$ $\qquad P_c = 13350000.00 \cdot \text{doll}$

**Annual Project Cash Flow - Uniform Portion Only**

$S_a := \left(Q_c \cdot C_{coal} + Q_{fo} \cdot C_{fuel\_oil} + Q_p \cdot C_{replace\_power}\right) + S_m - C_a$

$S_a = 3880000.00 \cdot \text{dolla}$

**Fill the Annualized Savings Array** - Uniform Annual Project Cash Flow Adjusted for Inflation

$$S_t := \left| \begin{array}{l} S_0 \leftarrow -P_c \\ S_1 \leftarrow S_a \cdot \left(1 + i_{inflation}\right) \\ \text{for } i \in 2..n \\ \quad S_i \leftarrow S_{i-1} \cdot \left(1 + i_{inflation}\right) \\ \text{return } S \end{array} \right.$$

**Future Salvage Entered into the Unequal Savings Array**

$S_{unequal_n} := S_{unequal_n} + L_n$

**Fill the Annualized Rate of Return Array** - Adjustments Made for Unequal Cost/Savings

$$ROR := \left| \begin{array}{l} R_0 \leftarrow -P_c \\ \text{for } i \in 1..n \\ \quad R_i \leftarrow S_{t_i} + fv\left(i_{inflation}, i, 0, S_{unequal_i}, 0\right) - fv\left(i_{inflation}, i, 0, C_{unequal_i}, 0\right) \\ \text{return } R \end{array} \right.$$

**Fill the Annualized Present Value Array** - Present Value Calculation on RoR Array

$$PPV := \left| \begin{array}{l} P_0 \leftarrow -P_c \\ \text{for } i \in 1..n \\ \quad P_i \leftarrow -pv\left(i_{money}, i, 0, ROR_i, 0\right) \\ \text{return } P \end{array} \right.$$

**Calculate the Net Present Value** - Sum the Period Present Value Array

$$NPV := \sum PPV$$

**Calculate the Present Value Annuity** - Sum the Period Present Value (PPV) Array Minus Net Project Cost ($P_c$)

$$APV := NPV - PPV_0$$

**Calculate the Benefit to Cost Ratio** - Present Value Annuity (APV) Divide by the Net Project Cost ($P_c$)

$$B2C := \frac{APV}{P_c}$$

**Calculate the Payback Period** - Net Project Cost ($P_c$) Divided by the Annual Cash Flow ($S_a$)

$$Payback := \frac{P_c}{S_a}$$

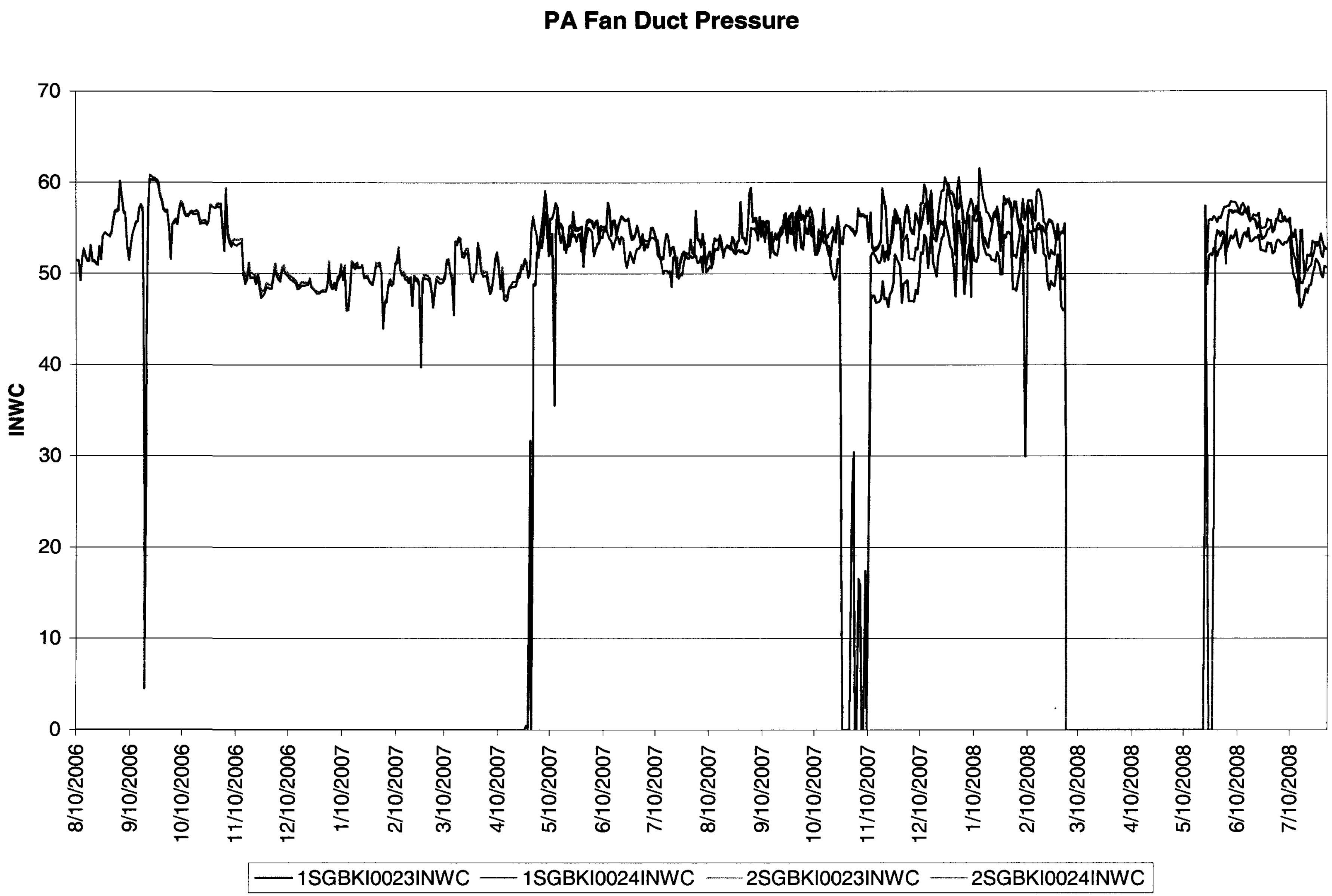
**Calculate the Rate of Return** - Ratio of Average Annual Cash Flow to Project Cost

$g := 0.1$ Initial Guess

$$ROI := irr(ROR, g)$$

## Results:

| | |
|---|---|
| **Present Value of Project:** | $NPV = 44634531 \cdot dollars$ |
| **Benefit / Cost Ratio:** | $B2C = 4.34$ |
| **Payback Period:** | $Payback = 3.4 \cdot years$ |
| **Rate of Return:** | $ROI = 32.7 \cdot \%$ |


PA Fan Duct Pressure
70
60
50
40
30
20
10
0
INWC
8/10/2006
9/10/2006
10/10/2006
11/10/2006
12/10/2006
1/10/2007
2/10/2007
3/10/2007
4/10/2007
5/10/2007
6/10/2007
7/10/2007
8/10/2007
9/10/2007
10/10/2007
11/10/2007
12/10/2007
1/10/2008
2/10/2008
3/10/2008
4/10/2008
5/10/2008
6/10/2008
7/10/2008
1SGBKI0023INWC
1SGBKI0024INWC
2SGBKI0023INWC
2SGBKI0024INWC

For the replacement of the dual speed motors

| | QTY | labor & material | total |
|---|---|---|---|
| New 6.9kV breaker + labor | 4 | $80,000.00 | $320,000.00 |
| new isolation transformer delta to delta + labor | 4 | $200,000.00 | $800,000.00 |
| new isolation transformer delta to wye + labor | 4 | $200,000.00 | $800,000.00 |
| VFD (dual set for one fan) with disconnect switch | 8 | $600,000.00 | $4,800,000.00 |
| power feeds cable + tray + installation ($15/ft) | 8 | $100,000.00 | $800,000.00 |
| DC link reactor + install+ fans and aux contact wiring | 8 | $120,000.00 | $960,000.00 |
| HVAC for VFD rooms and VFDs | 2 | $80,000.00 | $160,000.00 |
| Contract for installation of drives | 2 | $200,000.00 | $400,000.00 |
| enclosure + install | 2 | $200,000.00 | $400,000.00 |
| Building aux power lighting | 2 | $50,000.00 | $100,000.00 |
| Motor (PA - 4000 HP) dual winding | 4 | $890,000.00 | $3,560,000.00 |
| motor pedestal modification | 4 | $50,000.00 | $200,000.00 |
| controls installations and mat | 4 | $20,000.00 | $80,000.00 |
| engineering labor | 1 | $50,000.00 | $50,000.00 |
| aux power feeds each fan | 4 | $50,000.00 | $200,000.00 |
| | | total | $13,630,000.00 |